STORMWATER MANAGEMENT REPORT

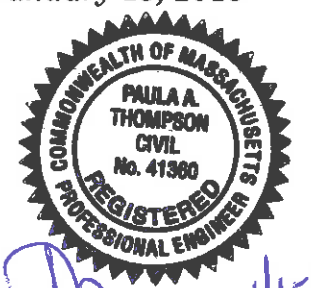
for:

Cummings School of Veterinary Medicine
at Tufts University
Small Animal Hospital Addition & Renovation – Remote Parking
Grafton, Massachusetts

Project Proponent:

Tufts University
200 Westboro Road
North Grafton, MA 01536

January 15, 2015



1/15/15

Paula A. Thompson, P.E.

WATERMAN DESIGN ASSOCIATES, INC.
31 East Main Street • Westborough, MA 01581

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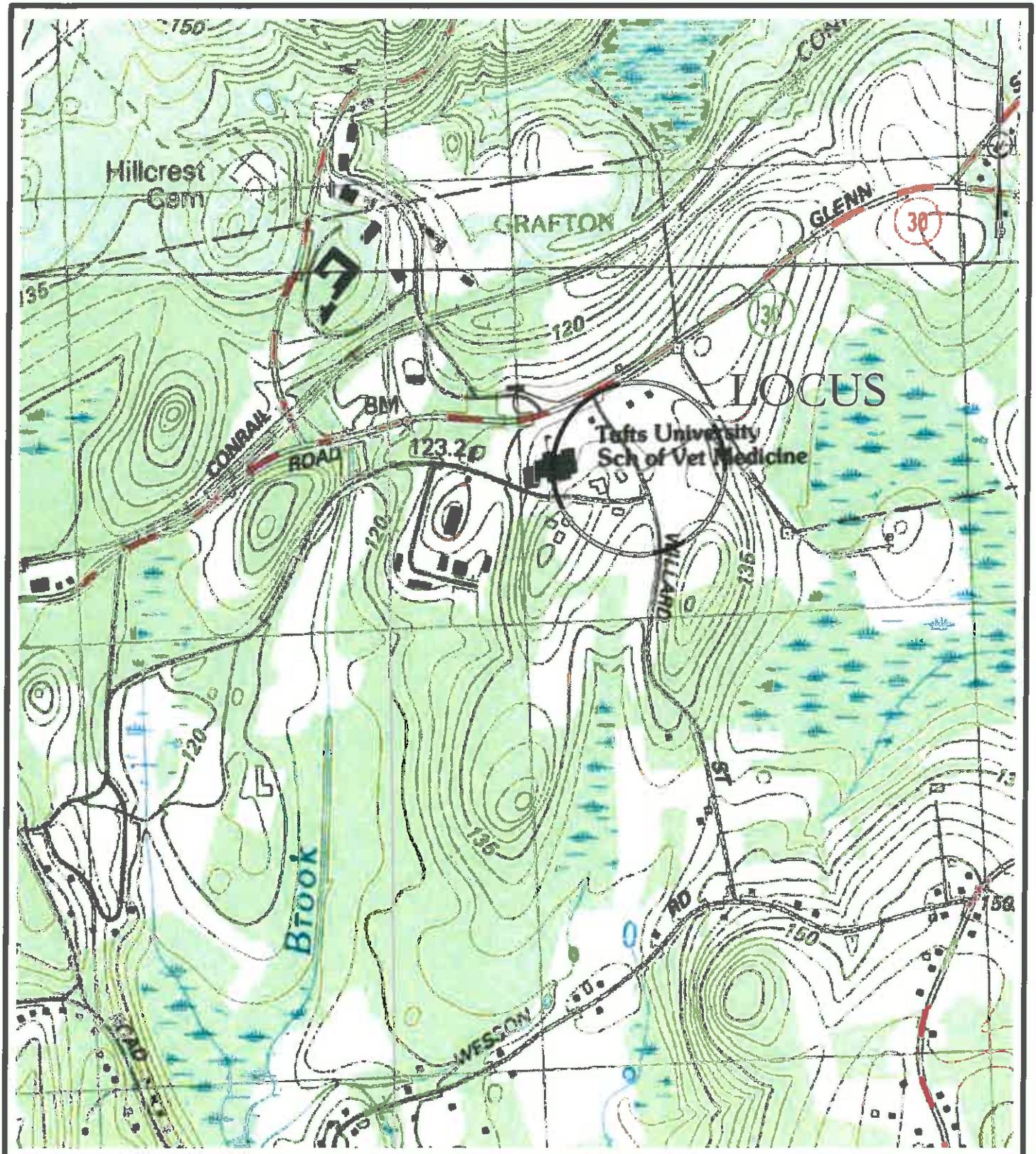


PREPARED BY:

WATERMAN DESIGN ASSOCIATES, INC.

31 East Main Street
Westborough, MA 01581

508.366.6552
(fax) 508.366.6506
watermandesign.com wda@wdassoc.com

TITLE:	LOCUS MAP Small Animal Hospital Addition and Renovation Tufts University
APPLICANT:	TUFTS UNIVERSITY 200 Westboro Road North Grafton, MA
SOURCE:	USGS Topographic Map Milford and Worcester South Quadrangles

DATE:	01/15/15	*FILE NO.:*	0016001	*SCALE:*	1" = 1000'
JOB NO.:	0016.15	*DWG NO.:*	0016004A	*DRAWN BY:*	pt

PURPOSE

Hydrologic calculations have been performed as part of the Site Plan Application for the remote parking area proposed for the Small Animal Hospital Addition and Renovation at Cummings School of Veterinary Medicine (Tufts) in Grafton, MA. The calculations were performed to design stormwater collection and attenuation facilities for the site and to demonstrate that the project will meet the standards of the Town of Grafton. As the project is well under 40,000 square feet and will not include the excavation of more than 1000 cubic yards of material, the project is not subject to a permit under the Grafton Stormwater Bylaw.

This report describes the existing project site, the proposed project, and analyses performed to develop a stormwater management system that will protect public safety and convenience and minimize environmental impacts.

PROJECT SITE

The subject site contains approximately 16,000 square feet and is located on the south side of existing Wildlife Center on the Tufts campus. The existing site consists of a small parking area, associated driveway, and existing field area. The site generally drains from west to east and elevations range from 464' to 444'. The existing un-curbed parking area is graded toward the field. There are no existing stormwater quality or quantity controls.

United States Department of Agriculture Natural Resources Conservation Service (NRCS) mapping identifies the soils of the subject site as Woodbridge fine sandy loam (HSG C). Soil testing has not been performed as part of this project, however historic excavations in the area indicated soil types consistent with NRCS mapping. Seasonal high groundwater is evidenced by the seasonal intermittent stream and bordering vegetated wetland (BVW) located approximately 110 feet from the edge of the project site. The BVW boundary was confirmed by the Conservation Commission (Order of Conditions DEP #164-887 and Grafton Wetlands Bylaw Permit #720 issued 10/23/14).

No portion of the subject site contains an area of Priority Habitat of Rare Species or Estimated Habitat of Rare Wildlife as shown on Massachusetts Natural Heritage Atlas, 13th Edition, Effective October 1, 2008. No portion of the subject site contains Special Flood Hazard Area (i.e., 100-year flood zone), as shown on the NFIP Flood Insurance Rate Map for Worcester County, Massachusetts (Map Number 25027C0831F, Effective Date July 16, 2014).

The attached Existing Hydrology Plan shows the project design point and contributing drainage area(s) with existing cover types.

PROPOSED PROJECT

The project proponent, Tufts, proposes to expand the existing parking at the Wildlife Center by 20 new parking spaces and construct a new stormwater management system to improve water quality and control stormwater runoff.

All stormwater runoff from the parking area will be graded overland to a proposed grass swale and then to the proposed detention basin. Controlled outflow will be discharged to the upland area at a rate equal to or less than existing conditions for the 2, 10, and 100-year, 24-hour design storms.

Low Impact Development (LID) Considerations:

The Tufts campus is, in itself, a low impact development. The total impervious area within a 1000-foot radius development circle is only 18.9+/- acres (about 26% impervious). The project is consistent with intent of the Campus Development Overlay District regulations.

STORMWATER MANAGEMENT STANDARDS

STANDARD #1 – NO NEW UNTREATED DISCHARGES

The stormwater management system has been designed so that all stormwater runoff from the parking area is treated through a treatment train consisting of grass swale for pretreatment and detention basin. The outlet has been designed so that there will be no erosion or scour.

STANDARD #2 – PEAK RATE ATTENUATION

METHODOLOGY

United States Soil Conservation Service, "Urban Hydrology for Small Watersheds, Technical Release Number 55" (TR-55) methods (HydroCAD 10.00) were utilized to develop runoff hydrographs for watershed areas affected by the proposed development. Existing and proposed runoff hydrographs were developed for the 2, 10, and 100-year, 24-hour rainfall events for the purpose of developing a stormwater management system that will limit post-development peak runoff rates to pre-development levels.

The proposed stormwater management system has been designed to meet the requirements of the Town of Grafton. The project will limit peak rates of runoff from the site and will infiltrate runoff during periods of low groundwater to approximate existing groundwater recharge.

ANALYSIS SUMMARY

In order to assess the impact of the proposed development on peak runoff rates onto down-gradient properties, hydrologic calculations were performed for each of three design storms at the design point. The calculations refer to runoff quantities at the final design point, the existing swale located along the existing gravel driveway east of the project area.

Calculations of peak runoff rates for existing and proposed site conditions are included and summarized in Table I for comparison of peak runoff rates at the design point for the three design storms. A proposed hydrology plan is provided showing the sub-watersheds draining to the proposed stormwater management facilities. Stormwater runoff from the overland areas not tributary to the stormwater management facilities will drain by sheet flow or shallow concentrated flow along the existing flow patterns to the design point.

Table I demonstrates that the proposed stormwater management system will be effective in limiting peak rates of runoff from the subject site to approximate pre-development levels.

TABLE I: EXISTING AND PROPOSED PEAK RUNOFF

DRAINAGE AREA	DESIGN STORM EVENT / PEAK RUNOFF (cfs)		
	2-Year	10-Year	100-Year
Existing	3.0	6.1	10.7
Proposed	2.1	4.3	10.7

STANDARD #3 – STORMWATER RECHARGE

We anticipate that seasonal high groundwater conditions and slow permeability of the existing soils limit the ability of the soils to recharge groundwater under existing conditions (as evidenced by the seasonal breakout of groundwater at the intermittent stream and associated bordering vegetated wetland.)

During periods of low groundwater the proposed grass swale and detention basin will provide the opportunity for groundwater recharge. The outlet of the detention basin has been set 1.8' higher than the bottom of the basin to allow the capture and retention of stormwater to promote recharge. No exfiltration rate was used in our hydrologic models for the basin. The Static Method was used to size the storage volume below the basin outlet (volume = 0.25" over the proposed impervious area of 4,730 sf). Conservatively, the lowest Rawl's Rate for HSG C soils (0.17 in/hr) was used to determine the drawdown.

REQUIRED (CF)	PROVIDED (CF)
100	2,575

DRAWDOWN CALCULATIONS

$$Time = \frac{Rv}{(K)(BottomArea)}$$

Rv = Recharge Volume (cubic feet)

K = Saturated Hydraulic Conductivity (inches per hour)

$$Time = \frac{100cf}{(0.17in/hr)(1ft/12in)(1{,}030sf)}$$

Time = 7 hours < 72 hours required

STANDARD #4 – WATER QUALITY

Water quality measures are designed to treat 0.5 inch of runoff prior to discharging to the upland area. The water quality volume is achieved by providing a static storage volume below the outlet in the basin.

REQUIRED (CF)	PROVIDED (CF)
200	2,575

STANDARD #5 – LAND USES WITH HIGHER POTENTIAL POLLUTANT LOADS (LUHPPLS)

The proposed project is not considered a land use with Higher Potential Pollutant Loads therefore, Standard #5 is not applicable.

STANDARD #6 – CRITICAL AREAS

The proposed project is not discharging near or to a Critical Area therefore, Standard #6 is not applicable.

STANDARD #7 – REDEVELOPMENT PROJECT

The new paved area is not considered a redevelopment project therefore, Standard #7 is not applicable.

STANDARD #8 – CONSTRUCTION POLLUTION PREVENTION AND EROSION AND SEDIMENTATION CONTROL

As the total project area less than one acre, a Notice of Intent (NOI) is not required to be filed with the US EPA. The attached project plans outline the minimum measures necessary to control erosion and prevent pollution and sedimentation during construction.

STANDARD #9 – OPERATION AND MAINTENANCE PLAN

The attached Operation and Maintenance Plan describes the requisite long-term operation and maintenance of the on-site stormwater Best Management Practices (BMPs). The Operation and Maintenance Plan also describes source control for the prevention of pollution to also serve as the Long Term Pollution Prevention Plan (LTPPP).

STANDARD #10 – PROHIBITION OF ILLICIT DISCHARGES

An Illicit Discharge Compliance Statement will be provided by the Owner/Applicant prior to the discharge of stormwater to post-construction BMPs. No illicit discharges are proposed as part of this project.

OPERATION AND MAINTENANCE PLAN
LONG TERM POLLUTION PREVENTION PLAN

Remote Parking Expansion
(located at the Wildlife Center)
Tufts University
North Grafton, MA

APPLICANT:

Tufts University
200 Westboro Road
North Grafton, Massachusetts 01536

RESPONSIBILITY:

The Owner will be responsible for implementation of the Operation and Maintenance Plan for the stormwater management system and Long Term Pollution Prevention Plan for the project and for any corrective action required.

SITE CONDITIONS:

The stormwater management system for the site includes a grass swale and detention basin.

LAWN/LANDSCAPE MAINTENANCE:

1. Apply pesticides and fertilizers properly; at the proper time of year and at proper application rates to ensure absorption.
2. Limit lawn watering: chose drought-tolerant landscaping and grasses, and use mulch and compost to retain moisture.
3. Under no circumstance shall the stormwater management system be used for yard waste and landscape debris.

DEICING:

1. The use and loading rates for application of deicing salts should be reduced to a minimum to maintain safe vehicular and pedestrian travel.
2. Alternative materials such as sand or gravel, calcium chloride, and calcium magnesium acetate should be considered in areas adjacent stormwater management facilities and resource areas.
3. Deicing materials shall be covered to prevent loss and migration.
4. Under no circumstance shall the stormwater management system be used for storage of deicing materials.

SNOW MANAGEMENT:

1. Snow shall be stockpiled in pervious areas where it can slowly infiltrate. Under no circumstance shall the stormwater management system be used for snow storage.
2. Avoid dumping/piling snow in grass swale to prevent blockages and localized ponding.
3. Sediments deposited from the snow storage areas shall be removed every spring.

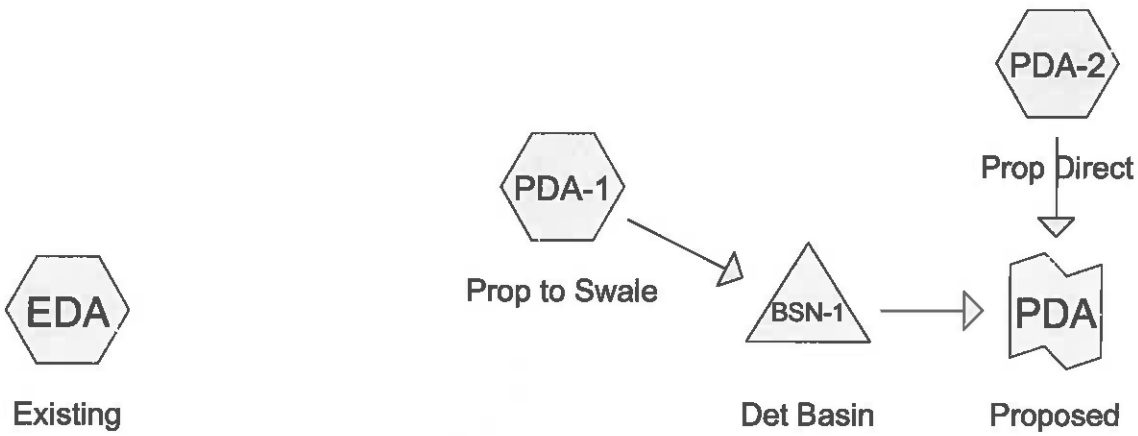
SWEEPING OF PAVED SURFACES:

1. All paved surfaces on-site including driveways, loading areas, and parking areas shall be swept at least once annually to remove accumulations of sand, silt, leaves, and other debris.
2. Sweeping should occur in March/April after snowmelt has occurred and thaw has begun. Sweepings shall be disposed of at an appropriate location away from resource areas (wetlands or waterways) and stormwater management facilities.

DETENTION BASIN and GRASS SWALE:

1. The basin and swale shall be inspected for accumulated sediment at least twice per year and sediment shall be removed when depth is 12 inches or at least once every 10 years.
2. Basin shall be inspected at least twice per year and immediately following large storm events to determine if the basin is functioning as intended. Inspections should be conducted during wet weather to determine if the basin is meeting the targeted detention times (24 hour average detention time). The basin shall be checked for slope integrity, soil moisture, vegetative health, soil stability, soil compaction, soil erosion, ponding, and sedimentation. Any necessary repairs shall be made immediately.
3. During the first few months following construction, the basin and swale shall be inspected to ensure that the proposed vegetation becomes adequately established.
4. At least twice during the growing season, the swale, basin, side slopes, and embankments shall be mowed and accumulated trash and debris removed.
5. To maintain the dense growth of vegetation, periodic reseeding shall be performed.
6. Basin and swale shall not be used for snow removal and yard waste disposal.
7. Riprap spillway shall be checked a minimum of once per year for evidence of clogging or flow restrictions and cleared as necessary. Any debris or accumulated sediments which could hinder flows shall be removed and disposed.

EXISTING & PROPOSED HYDROLOGY



Subcat Reach Pond Link

Routing Diagram for 001615_hyd01
Prepared by Waterman Design Associates, Inc., Printed 1/14/2015
HydroCAD® 10.00 s/n 01522 © 2013 HydroCAD Software Solutions LLC

Time span=0.00-48.00 hrs, dt=0.05 hrs, 961 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment EDA: Existing
Runoff Area=91,100 sf 21.06% Impervious Runoff Depth=1.27"
Tc=6.0 min CN=78 Runoff=3.0 cfs 9,667 cf

Subcatchment PDA-1: Prop to Swale
Runoff Area=24,400 sf 56.56% Impervious Runoff Depth=1.84"
Tc=6.0 min CN=86 Runoff=1.2 cfs 3,731 cf

Subcatchment PDA-2: Prop Direct
Runoff Area=66,700 sf 15.17% Impervious Runoff Depth=1.21"
Tc=6.0 min CN=77 Runoff=2.1 cfs 6,736 cf

Pond BSN-1: Det Basin
Peak Elev=445.82' Storage=2,614 cf Inflow=1.2 cfs 3,731 cf
Outflow=0.1 cfs 1,156 cf

Link PDA: Proposed
Inflow=2.1 cfs 7,892 cf
Primary=2.1 cfs 7,892 cf

Summary for Subcatchment EDA: Existing

Runoff = 3.0 cfs @ 12.10 hrs, Volume= 9,667 cf, Depth= 1.27"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type III 24-hr 2-year Rainfall=3.20"

Area (sf)	CN	Description
19,190	98	Paved parking, HSG C
3,780	96	Gravel surface, HSG C
68,130	71	Meadow, non-grazed, HSG C
91,100	78	Weighted Average
71,910		78.94% Pervious Area
19,190		21.06% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment PDA-1: Prop to Swale

Runoff = 1.2 cfs @ 12.09 hrs, Volume= 3,731 cf, Depth= 1.84"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type III 24-hr 2-year Rainfall=3.20"

Area (sf)	CN	Description
13,800	98	Paved parking, HSG C
10,600	71	Meadow, non-grazed, HSG C
24,400	86	Weighted Average
10,600		43.44% Pervious Area
13,800		56.56% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Minimum**

Summary for Subcatchment PDA-2: Prop Direct

Runoff = 2.1 cfs @ 12.10 hrs, Volume= 6,736 cf, Depth= 1.21"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type III 24-hr 2-year Rainfall=3.20"

Area (sf)	CN	Description
10,120	98	Paved parking, HSG C
3,780	96	Gravel surface, HSG C
52,800	71	Meadow, non-grazed, HSG C
66,700	77	Weighted Average
56,580		84.83% Pervious Area
10,120		15.17% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Pond BSN-1: Det Basin

Inflow Area = 24,400 sf, 56.56% Impervious, Inflow Depth = 1.84" for 2-year event
Inflow = 1.2 cfs @ 12.09 hrs, Volume= 3,731 cf
Outflow = 0.1 cfs @ 14.17 hrs, Volume= 1,156 cf, Atten= 94%, Lag= 124.7 min
Primary = 0.1 cfs @ 14.17 hrs, Volume= 1,156 cf

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Peak Elev= 445.82' @ 14.17 hrs Surf.Area= 1,841 sf Storage= 2,614 cf

Plug-Flow detention time= 355.6 min calculated for 1,155 cf (31% of inflow)
Center-of-Mass det. time= 225.7 min (1,048.3 - 822.5)

Volume	Invert	Avail.Storage	Storage Description
#1	444.00'	5,140 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
444.00	1,030	0	0
446.00	1,920	2,950	2,950
447.00	2,460	2,190	5,140

Device	Routing	Invert	Outlet Devices
#1	Primary	445.80'	**8.0' long x 8.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 Coef. (English) 2.43 2.54 2.70 2.69 2.68 2.68 2.66 2.64 2.64 2.64 2.65 2.65 2.66 2.66 2.68 2.70 2.74

Primary OutFlow Max=0.1 cfs @ 14.17 hrs HW=445.82' (Free Discharge)
↑—**1=Broad-Crested Rectangular Weir** (Weir Controls 0.1 cfs @ 0.36 fps)

Summary for Link PDA: Proposed

Inflow Area = 91,100 sf, 26.26% Impervious, Inflow Depth = 1.04" for 2-year event
Inflow = 2.1 cfs @ 12.10 hrs, Volume= 7,892 cf
Primary = 2.1 cfs @ 12.10 hrs, Volume= 7,892 cf, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Time span=0.00-48.00 hrs, dt=0.05 hrs, 961 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment EDA: Existing — Runoff Area=91,100 sf 21.06% Impervious Runoff Depth=2.54"
Tc=6.0 min CN=78 Runoff=6.1 cfs 19,304 cf

Subcatchment PDA-1: Prop to Swale — Runoff Area=24,400 sf 56.56% Impervious Runoff Depth=3.28"
Tc=6.0 min CN=86 Runoff=2.1 cfs 6,671 cf

Subcatchment PDA-2: Prop Direct — Runoff Area=66,700 sf 15.17% Impervious Runoff Depth=2.46"
Tc=6.0 min CN=77 Runoff=4.3 cfs 13,654 cf

Pond BSN-1: Det Basin — Peak Elev=445.95' Storage=2,854 cf Inflow=2.1 cfs 6,671 cf
Outflow=1.1 cfs 4,096 cf

Link PDA: Proposed — Inflow=4.3 cfs 17,750 cf
Primary=4.3 cfs 17,750 cf

Summary for Subcatchment EDA: Existing

Runoff = 6.1 cfs @ 12.09 hrs, Volume= 19,304 cf, Depth= 2.54"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type III 24-hr 10-year Rainfall=4.80"

Area (sf)	CN	Description
19,190	98	Paved parking, HSG C
3,780	96	Gravel surface, HSG C
68,130	71	Meadow, non-grazed, HSG C
91,100	78	Weighted Average
71,910		78.94% Pervious Area
19,190		21.06% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment PDA-1: Prop to Swale

Runoff = 2.1 cfs @ 12.09 hrs, Volume= 6,671 cf, Depth= 3.28"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type III 24-hr 10-year Rainfall=4.80"

Area (sf)	CN	Description
13,800	98	Paved parking, HSG C
10,600	71	Meadow, non-grazed, HSG C
24,400	86	Weighted Average
10,600		43.44% Pervious Area
13,800		56.56% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Minimum**

Summary for Subcatchment PDA-2: Prop Direct

Runoff = 4.3 cfs @ 12.09 hrs, Volume= 13,654 cf, Depth= 2.46"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type III 24-hr 10-year Rainfall=4.80"

Area (sf)	CN	Description
10,120	98	Paved parking, HSG C
3,780	96	Gravel surface, HSG C
52,800	71	Meadow, non-grazed, HSG C
66,700	77	Weighted Average
56,580		84.83% Pervious Area
10,120		15.17% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Pond BSN-1: Det Basin

Inflow Area = 24,400 sf, 56.56% Impervious, Inflow Depth = 3.28" for 10-year event
Inflow = 2.1 cfs @ 12.09 hrs, Volume= 6,671 cf
Outflow = 1.1 cfs @ 12.23 hrs, Volume= 4,096 cf, Atten= 46%, Lag= 8.6 min
Primary = 1.1 cfs @ 12.23 hrs, Volume= 4,096 cf

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Peak Elev= 445.95' @ 12.23 hrs Surf.Area= 1,898 sf Storage= 2,854 cf

Plug-Flow detention time= 187.4 min calculated for 4,092 cf (61% of inflow)
Center-of-Mass det. time= 85.1 min (891.1 - 806.0)

Volume	Invert	Avail.Storage	Storage Description
#1	444.00'	5,140 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
444.00	1,030	0	0
446.00	1,920	2,950	2,950
447.00	2,460	2,190	5,140

Device	Routing	Invert	Outlet Devices
#1	Primary	445.80'	**8.0' long x 8.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 Coef. (English) 2.43 2.54 2.70 2.69 2.68 2.68 2.66 2.64 2.64 2.64 2.65 2.65 2.66 2.66 2.68 2.70 2.74

Primary OutFlow Max=1.1 cfs @ 12.23 hrs HW=445.95' (Free Discharge)
↑—**1=Broad-Crested Rectangular Weir** (Weir Controls 1.1 cfs @ 0.94 fps)

Summary for Link PDA: Proposed

Inflow Area = 91,100 sf, 26.26% Impervious, Inflow Depth = 2.34" for 10-year event
Inflow = 4.3 cfs @ 12.10 hrs, Volume= 17,750 cf
Primary = 4.3 cfs @ 12.10 hrs, Volume= 17,750 cf, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Time span=0.00-48.00 hrs, dt=0.05 hrs, 961 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment EDA: Existing — Runoff Area=91,100 sf 21.06% Impervious Runoff Depth=4.47"
Tc=6.0 min CN=78 Runoff=10.7 cfs 33,971 cf

Subcatchment PDA-1: Prop to Swale — Runoff Area=24,400 sf 56.56% Impervious Runoff Depth=5.37"
Tc=6.0 min CN=86 Runoff=3.3 cfs 10,910 cf

Subcatchment PDA-2: Prop Direct — Runoff Area=66,700 sf 15.17% Impervious Runoff Depth=4.37"
Tc=6.0 min CN=77 Runoff=7.6 cfs 24,267 cf

Pond BSN-1: Det Basin — Peak Elev=446.09' Storage=3,127 cf Inflow=3.3 cfs 10,910 cf
Outflow=3.1 cfs 8,335 cf

Link PDA: Proposed — Inflow=10.7 cfs 32,602 cf
Primary=10.7 cfs 32,602 cf

Summary for Subcatchment EDA: Existing

Runoff = 10.7 cfs @ 12.09 hrs, Volume= 33,971 cf, Depth= 4.47"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type III 24-hr 100-year Rainfall=7.00"

Area (sf)	CN	Description
19,190	98	Paved parking, HSG C
3,780	96	Gravel surface, HSG C
68,130	71	Meadow, non-grazed, HSG C
91,100	78	Weighted Average
71,910		78.94% Pervious Area
19,190		21.06% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment PDA-1: Prop to Swale

Runoff = 3.3 cfs @ 12.09 hrs, Volume= 10,910 cf, Depth= 5.37"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type III 24-hr 100-year Rainfall=7.00"

Area (sf)	CN	Description
13,800	98	Paved parking, HSG C
10,600	71	Meadow, non-grazed, HSG C
24,400	86	Weighted Average
10,600		43.44% Pervious Area
13,800		56.56% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Minimum**

Summary for Subcatchment PDA-2: Prop Direct

Runoff = 7.6 cfs @ 12.09 hrs, Volume= 24,267 cf, Depth= 4.37"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type III 24-hr 100-year Rainfall=7.00"

Area (sf)	CN	Description
10,120	98	Paved parking, HSG C
3,780	96	Gravel surface, HSG C
52,800	71	Meadow, non-grazed, HSG C
66,700	77	Weighted Average
56,580		84.83% Pervious Area
10,120		15.17% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Pond BSN-1: Det Basin

Inflow Area = 24,400 sf, 56.56% Impervious, Inflow Depth = 5.37" for 100-year event
Inflow = 3.3 cfs @ 12.09 hrs, Volume= 10,910 cf
Outflow = 3.1 cfs @ 12.12 hrs, Volume= 8,335 cf, Atten= 6%, Lag= 1.9 min
Primary = 3.1 cfs @ 12.12 hrs, Volume= 8,335 cf

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Peak Elev= 446.09' @ 12.12 hrs Surf.Area= 1,969 sf Storage= 3,127 cf

Plug-Flow detention time= 137.8 min calculated for 8,327 cf (76% of inflow)
Center-of-Mass det. time= 56.1 min (848.3 - 792.3)

Volume	Invert	Avail.Storage	Storage Description
#1	444.00'	5,140 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
444.00	1,030	0	0
446.00	1,920	2,950	2,950
447.00	2,460	2,190	5,140

Device	Routing	Invert	Outlet Devices
#1	Primary	445.80'	**8.0' long x 8.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 Coef. (English) 2.43 2.54 2.70 2.69 2.68 2.68 2.66 2.64 2.64 2.64 2.65 2.65 2.66 2.66 2.68 2.70 2.74

Primary OutFlow Max=3.0 cfs @ 12.12 hrs HW=446.09' (Free Discharge)
↑—**1=Broad-Crested Rectangular Weir** (Weir Controls 3.0 cfs @ 1.32 fps)

Summary for Link PDA: Proposed

Inflow Area = 91,100 sf, 26.26% Impervious, Inflow Depth = 4.29" for 100-year event
Inflow = 10.7 cfs @ 12.10 hrs, Volume= 32,602 cf
Primary = 10.7 cfs @ 12.10 hrs, Volume= 32,602 cf, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Stage-Area-Storage for Pond BSN-1: Det Basin

Elevation (feet)	Surface (sq-ft)	Storage (cubic-feet)	Elevation (feet)	Surface (sq-ft)	Storage (cubic-feet)	Elevation (feet)	Surface (sq-ft)	Storage (cubic-feet)
444.00	1,030	0	445.32	1,617	1,747	446.64	2,266	4,289
444.02	1,039	21	445.34	1,626	1,780	446.66	2,276	4,335
444.04	1,048	42	445.36	1,635	1,812	446.68	2,287	4,380
444.06	1,057	63	445.38	1,644	1,845	446.70	2,298	4,426
444.08	1,066	84	445.40	1,653	1,878	446.72	2,309	4,472
444.10	1,075	105	445.42	1,662	1,911	446.74	2,320	4,519
444.12	1,083	127	445.44	1,671	1,945	446.76	2,330	4,565
444.14	1,092	149	445.46	1,680	1,978	446.78	2,341	4,612
444.16	1,101	170	445.48	1,689	2,012	446.80	2,352	4,659
444.18	1,110	193	445.50	1,698	2,046	446.82	2,363	4,706
444.20	1,119	215	445.52	1,706	2,080	446.84	2,374	4,753
444.22	1,128	237	445.54	1,715	2,114	446.86	2,384	4,801
444.24	1,137	260	445.56	1,724	2,148	446.88	2,395	4,849
444.26	1,146	283	445.58	1,733	2,183	446.90	2,406	4,897
444.28	1,155	306	445.60	1,742	2,218	446.92	2,417	4,945
444.30	1,164	329	445.62	1,751	2,253	446.94	2,428	4,993
444.32	1,172	352	445.64	1,760	2,288	446.96	2,438	5,042
444.34	1,181	376	445.66	1,769	2,323	446.98	2,449	5,091
444.36	1,190	400	445.68	1,778	2,358	447.00	**2,460**	**5,140**
444.38	1,199	424	445.70	1,786	2,394			
444.40	1,208	448	445.72	1,795	2,430			
444.42	1,217	472	445.74	1,804	2,466			
444.44	1,226	496	445.76	1,813	2,502			
444.46	1,235	521	445.78	1,822	2,538			
444.48	1,244	546	445.80	1,831	2,575			
444.50	1,253	571	445.82	1,840	2,612			
444.52	1,261	596	445.84	1,849	2,648			
444.54	1,270	621	445.86	1,858	2,686			
444.56	1,279	647	445.88	1,867	2,723			
444.58	1,288	672	445.90	1,875	2,760			
444.60	1,297	698	445.92	1,884	2,798			
444.62	1,306	724	445.94	1,893	2,836			
444.64	1,315	750	445.96	1,902	2,874			
444.66	1,324	777	445.98	1,911	2,912			
444.68	1,333	803	446.00	1,920	2,950			
444.70	1,341	830	446.02	1,931	2,989			
444.72	1,350	857	446.04	1,942	3,027			
444.74	1,359	884	446.06	1,952	3,066			
444.76	1,368	911	446.08	1,963	3,105			
444.78	1,377	939	446.10	1,974	3,145			
444.80	1,386	966	446.12	1,985	3,184			
444.82	1,395	994	446.14	1,996	3,224			
444.84	1,404	1,022	446.16	2,006	3,264			
444.86	1,413	1,050	446.18	2,017	3,304			
444.88	1,422	1,079	446.20	2,028	3,345			
444.90	1,430	1,107	446.22	2,039	3,385			
444.92	1,439	1,136	446.24	2,050	3,426			
444.94	1,448	1,165	446.26	2,060	3,467			
444.96	1,457	1,194	446.28	2,071	3,509			
444.98	1,466	1,223	446.30	2,082	3,550			
445.00	1,475	1,253	446.32	2,093	3,592			
445.02	1,484	1,282	446.34	2,104	3,634			
445.04	1,493	1,312	446.36	2,114	3,676			
445.06	1,502	1,342	446.38	2,125	3,719			
445.08	1,511	1,372	446.40	2,136	3,761			
445.10	1,520	1,402	446.42	2,147	3,804			
445.12	1,528	1,433	446.44	2,158	3,847			
445.14	1,537	1,463	446.46	2,168	3,890			
445.16	1,546	1,494	446.48	2,179	3,934			
445.18	1,555	1,525	446.50	2,190	3,978			
445.20	1,564	1,556	446.52	2,201	4,021			
445.22	1,573	1,588	446.54	2,212	4,066			
445.24	1,582	1,619	446.56	2,222	4,110			
445.26	1,591	1,651	446.58	2,233	4,154			
445.28	1,600	1,683	446.60	2,244	4,199			
445.30	1,609	1,715	446.62	2,255	4,244			

Storage below outlet

Summary for Reach CH: GrassChannel

Inflow Area = 24,400 sf, 56.56% Impervious, Inflow Depth = 5.37" for 100-year event
Inflow = 3.3 cfs @ 12.09 hrs, Volume= 10,910 cf
Outflow = 3.1 cfs @ 12.13 hrs, Volume= 10,910 cf, Atten= 6%, Lag= 2.4 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.68 fps, Min. Travel Time= 1.4 min ← Max velocity.
Avg. Velocity = 1.05 fps, Avg. Travel Time= 4.8 min

Peak Storage= 268 cf @ 12.11 hrs
Average Depth at Peak Storage= 0.31'
Bank-Full Depth= 1.00' Flow Area= 5.0 sf, Capacity= 35.3 cfs

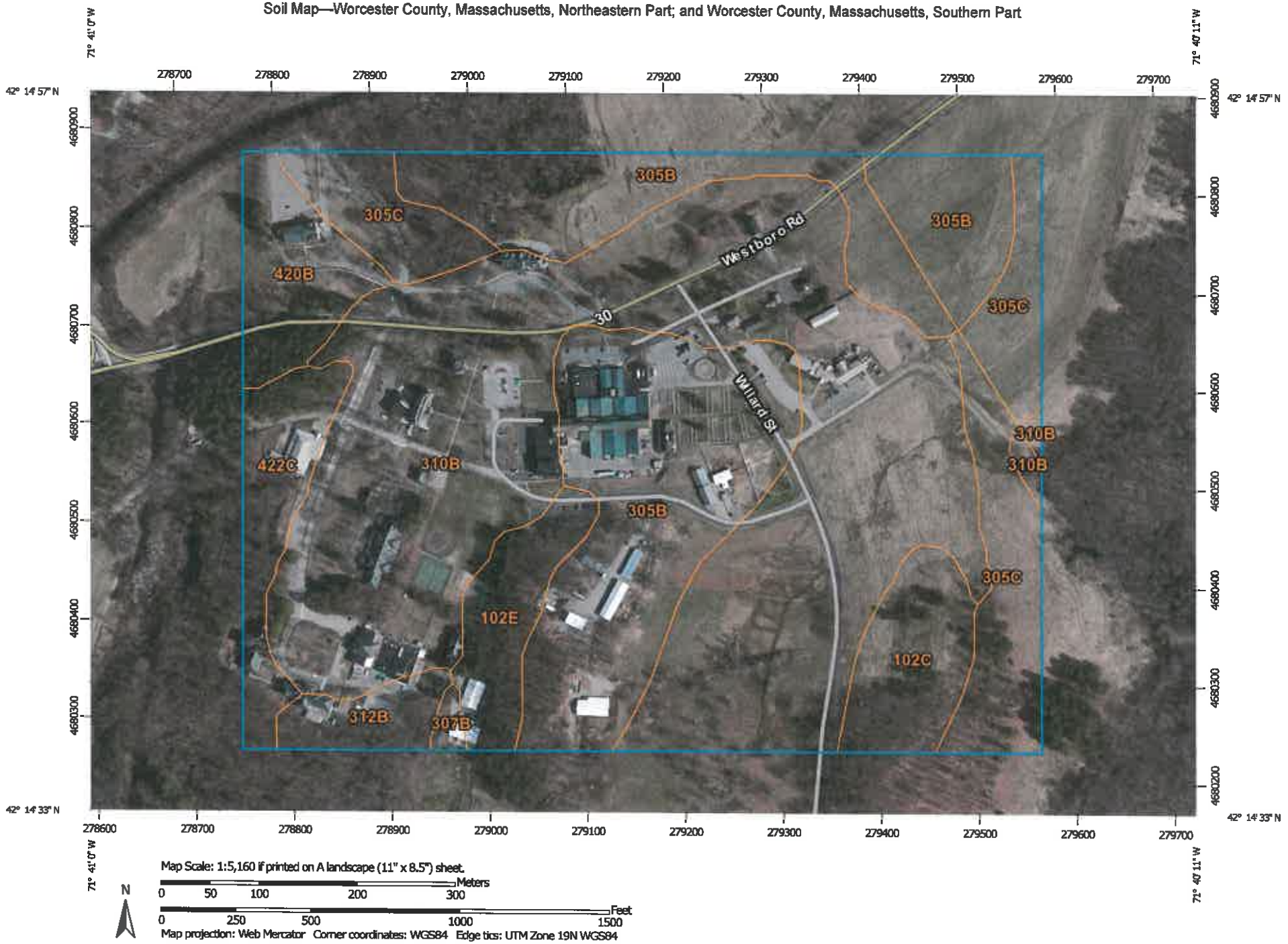
2.00' x 1.00' deep channel, n= 0.030 Stream, clean & straight
Side Slope Z-value= 3.0 '/' Top Width= 8.00'
Length= 300.0' Slope= 0.0400 '/'
Inlet Invert= 460.00', Outlet Invert= 448.00'

Flow through channel during 100yr storm to determine max velocity.

Channel to be constructed with jute matting to establish grass cover to prevent erosion.

APPENDICES

Soil Map—Worcester County, Massachusetts, Northeastern Part; and Worcester County, Massachusetts, Southern Part



Map Scale: 1:5,160 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0 50 100 200 300

Feet: 0 250 500 1000 1500

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 19N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at scales ranging from 1:20,000 to 1:25,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Worcester County, Massachusetts, Northeastern Part
Survey Area Data: Version 9, Sep 19, 2014

Soil Survey Area: Worcester County, Massachusetts, Southern Part
Survey Area Data: Version 7, Sep 22, 2014

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Mar 30, 2011—May 1, 2011

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Worcester County, Massachusetts, Northeastern Part (MA613)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
305B	Paxton fine sandy loam, 3 to 8 percent slopes	4.4	3.6%
305C	Paxton fine sandy loam, 8 to 15 percent slopes	3.0	2.5%
310B	Woodbridge fine sandy loam, 3 to 8 percent slopes	0.2	0.1%
Subtotals for Soil Survey Area		**7.6**	**6.2%**
Totals for Area of Interest		**123.4**	**100.0%**

Worcester County, Massachusetts, Southern Part (MA615)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
102C	Chatfield-Hollis-Rock outcrop complex, 3 to 15 percent slopes	5.2	4.2%
102E	Chatfield-Hollis-Rock outcrop complex, 15 to 35 percent slopes	4.5	3.7%
305B	Paxton fine sandy loam, 3 to 8 percent slopes	27.5	22.3%
305C	Paxton fine sandy loam, 8 to 15 percent slopes	9.8	8.0%
307B	Paxton fine sandy loam, 3 to 8 percent slopes, extremely stony	0.4	0.3%
310B	Woodbridge fine sandy loam, 3 to 8 percent slopes	55.4	44.9%
312B	Woodbridge fine sandy loam, 0 to 8 percent slopes, extremely stony	2.5	2.1%
420B	Canton fine sandy loam, 3 to 8 percent slopes	5.2	4.2%
422C	Canton fine sandy loam, 8 to 15 percent slopes, extremely stony	5.1	4.2%
Subtotals for Soil Survey Area		**115.8**	**93.8%**